INTRODUCTION

The reliance upon, and use of, radioactive material in agriculture, industry, and medicine continues to increase. As the manufacture, use, and disposal of radioactive material has increased, so has the need to transport it. Consequently, the potential for you as a responder to encounter an incident involving some type of radioactive material has increased. Having knowledge of radiological hazards, and the terminology used to describe them, will increase your ability to quickly recognize, safely respond, and accurately relay information during an incident involving radioactive material.

PURPOSE

Upon completion of this module, you will have a better understanding of the basic structure of an atom and the fundamentals of radiation.

MODULE OBJECTIVES

Upon completion of this module, you will be able to:

1. Identify the basic components of an atom.
2. Define ionizing radiation, radioactivity, radioactive material, and radioactive contamination.
3. Distinguish between radiation and contamination.
4. Identify common sources of radiation and radioactive material.

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BACKGROUND

Radiation is all around us and has been present since the birth of this planet. Today, both man-made and natural radioactive material are part of our daily lives. We use radioactive material for beneficial purposes, such as generating electricity and diagnosing and treating medical conditions. Radiation is used in many ways to improve our health and the quality of our lives.

In 1895, while working in his laboratory, Wilhelm Roentgen discovered a previously unknown phenomenon: rays that could penetrate solid objects. Roentgen called these rays X-rays. The figure at right shows Roentgen's wife's left hand - the first known X-ray. The practical uses of X-rays were quickly recognized and, within a few months, a medical X-ray picture was used to locate shotgun pellets in a man's hand.

In 1896, Henri Becquerel reported observing a similar radiological phenomenon caused by uranium ore. Later that year, Pierre and Marie Curie identified the source of the radiation as a small concentration of radium, a radioactive material, in the ore.

These discoveries set the stage for using radiation in medicine, industry, and research. Since that time, we have developed a detailed understanding of the hazards and benefits of radiation. In fact, scientists understand radiological hazards even better than hazards associated with many other physical and chemical agents we encounter.

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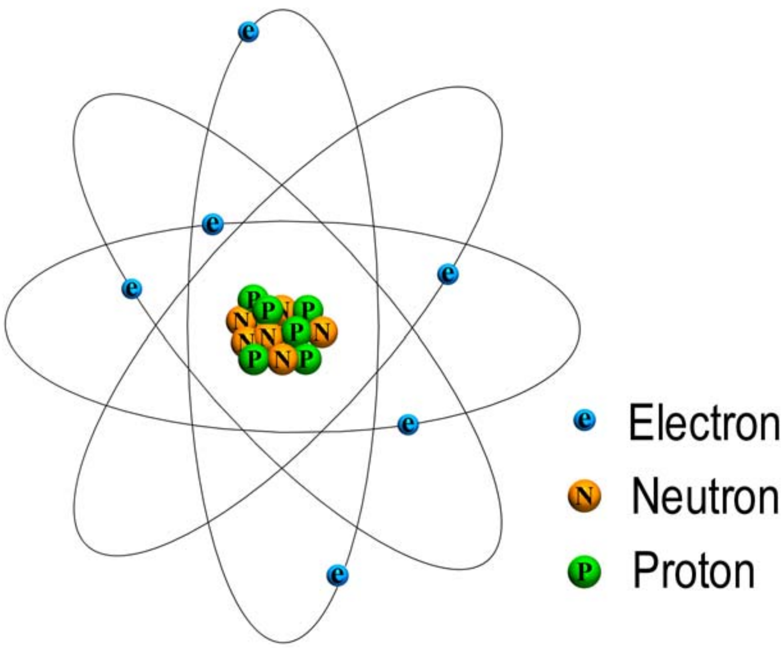
BASIC RADIOLOGICAL CONCEPTS

Atomic Structure

All matter is made up of atoms. Atoms are invisible to both the naked and assisted eye. The three basic components of the atom are protons, neutrons, and electrons. The central portion of the atom is the nucleus. The nucleus contains protons and neutrons, which are very close to each other. Electrons orbit the nucleus.



Protons

- Are located in the atom's nucleus
- Have a positive electrical charge
- Determine the element's identity

Neutrons

- Are located in the atom's nucleus
- Are electrically neutral
- Determine the nuclear properties of the atom

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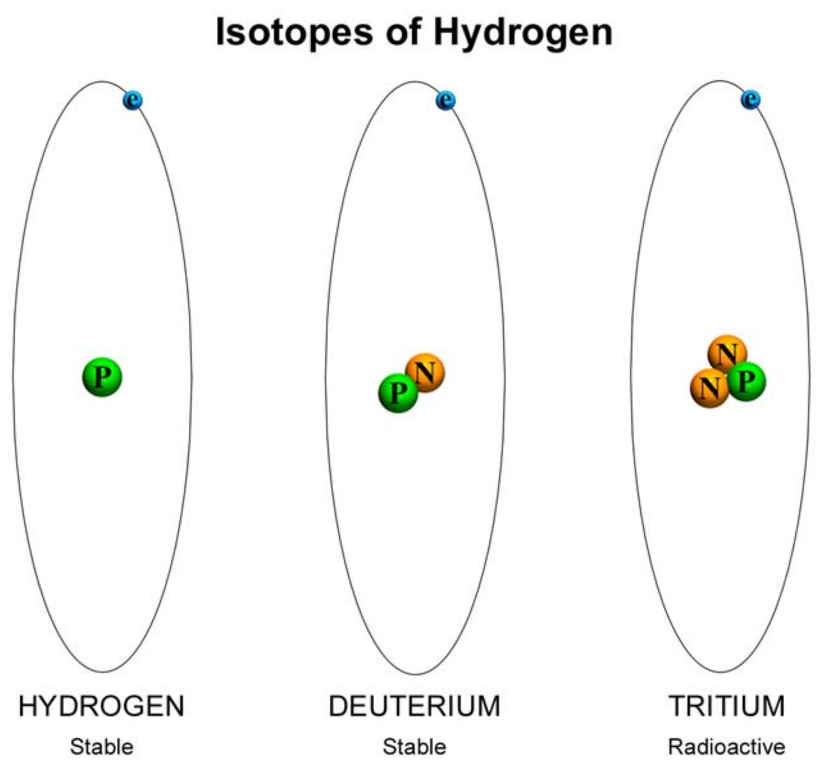
Atoms of the same element have the same number of protons but may have a different number of neutrons. These variants are called isotopes. Isotopes of the same element have the same chemical properties regardless of the number of neutrons. The nuclear-properties of isotopes, however, can be quite different. For example, the illustration below shows three isotopes of hydrogen. All three isotopes have the same chemical properties; however, tritium is a radioactive isotope or radioisotope.



Electrons

- Orbit the nucleus
- Have a negative electrical charge
- Determine the chemical properties of an atom

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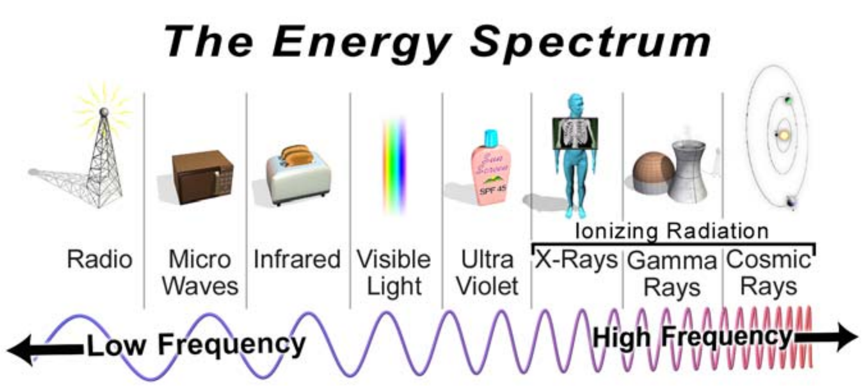
Stable and Unstable Atoms

Only certain combinations of neutrons and protons result in stable atoms.

- If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy. This atom will not be stable.
- An unstable atom will try to become stable by giving off excess energy in the form of radiation (particles or waves). Unstable atoms are also known as radioactive atoms.

IONIZING RADIATION

As an emergency responder, you may already be familiar with some radiation terminology and with some radiological concepts. When most people think of radiation, they think of the type we are talking about in this course—the type that comes from atoms. There are, however, many different kinds of radiation. Visible light, heat, radio waves, and microwaves are all types of radiation but they are not the type we are concerned about in this course. In this course, when we speak of radiation, we're talking about a type of radiation called ionizing radiation.



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Charged particles (e.g., electrons, protons) are called ions. The production of ions is called ionization. Ionizing radiation is more energetic than other types of radiation. Ionizing radiation has the ability to cause a physical change in atoms by making them electrically charged. This ability makes ionizing radiation hazardous.

Radioactive Material and Radioactivity

Radioactive material is any material that emits radiation. The process of an unstable atom emitting radiation is called radioactivity. Radioactive atoms can be generated through nuclear processes but they also exist naturally in things like uranium ore, thorium rock, and some forms of potassium. When a radioactive atom goes through the process of radioactivity, also called radioactive decay, it will change to another type of atom. In fact, a radioactive atom may change from one element to another element during the decay process. For example, the element uranium will eventually change through radioactive decay to lead. This stabilizing process may take from a fraction of a second to billions of years, depending on the particular type of atom.

The rate of radioactive decay is unique to each type of radioactive atom and is measured in half-lives, the time it takes for half of the radioactive atoms in a sample to decay to another form. Different radioactive materials have different half-lives. For example, some radioactive pharmaceutical products (called radiopharmaceuticals) have half-lives that range from a few hours to a few months. It is important to note that radioactivity, regardless of the material, is constantly decreasing. After seven half-lives, the material will be at <1% of its original activity.

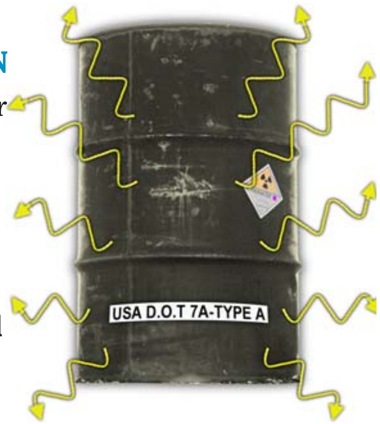
Radioactive Contamination

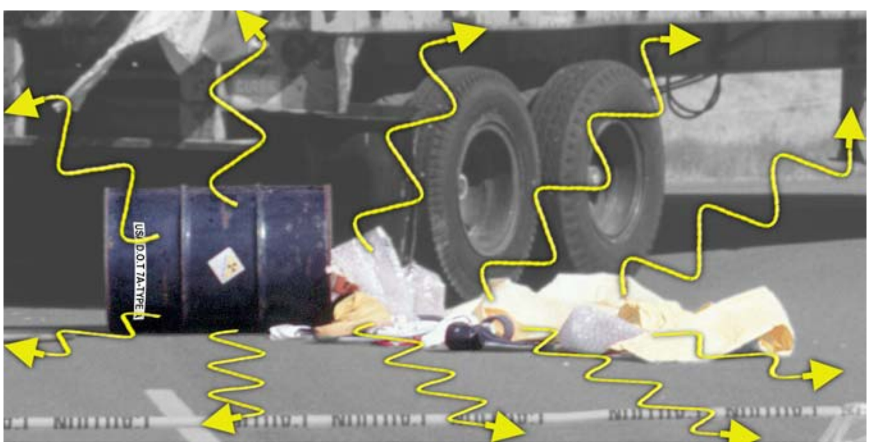
Any material that emits radiation is a radioactive material. If undesired radioactive material is deposited on the surfaces of or inside structures, areas, objects, or people, it is called radioactive contamination. Simply speaking, radioactive contamination is radioactive material in an unwanted location.

When radioactive material is properly used and controlled, there are many beneficial applications. Most smoke detectors, for instance, use radioactive material, as do certain medical diagnostic tools and treatment procedures. It is only when radioactive material is where it is not wanted (e.g., on the ground, in water, or on you) that we refer to it as contamination.

RADIATION VERSUS CONTAMINATION

One of the most important concepts for the responder to understand is the difference between radiation and contamination. Radiation is **energy** emitted by radioactive material. Contamination is radioactive **material** in a location where it is not wanted.





A person can be exposed to radiation and not become contaminated. On the other hand, radioactive contamination emits radiation. If a person is contaminated with radioactive material, the person continues to be exposed to radiation until the contamination is removed.

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Put another way, radiation exposure is like being in front of a heat lamp. When the lamp is on, you can feel the heat. When you turn the lamp off, the heat is no longer felt. The heat is similar to exposure. The source of the energy is not in or on you and the exposure stops when you turn off the lamp. Contamination of a person happens when the source of radiation (radioactive material) gets on or in the person. You can be exposed to radiation and not be contaminated. However, if you become contaminated, you will continue to be exposed to radiation until the contamination is removed.

Exposure to Radioactive Material

If you encounter radioactive material at an incident scene, you may be exposed to radiation. Even with the tightest package and the best protection, low levels of radiation can pass through the package. This radiation is at a level that is (based on numerous scientific studies by a variety of industry, scientific, and government organizations) considered safe for people working near the packages. If the packages are intact, you should not expect unsafe exposure.

You should remember that we are exposed to radiation every day from common sources such as cosmic rays, X-rays, and even the bricks used to make buildings. Being exposed to radiation at these controlled levels does not constitute a hazard and should not prevent you from taking normal emergency actions. Exposure to radiation alone will not contaminate you.

Radioactive Contamination Types

A more serious concern is the possibility of radioactive contamination. The probability of radioactive material being released during an incident is extremely low. If radioactive material is released, it is possible for responders, victims, and onlookers to become contaminated. This is especially true where the material is in the form of a liquid or powder. Radioactive contamination can come in two basic types: internal or external. Radioactive contamination is serious because as long as the material is on you, or your clothing, or inside your body, you are still being exposed. While a short exposure to these materials may be safe, prolonged or very close exposure may not be.

A special concern is the possibility of internal contamination. This happens when a radioactive material—usually a liquid, powder, or gas—is accidentally ingested or inhaled. Once inside the body, it can be difficult to remove.

Another concern is that people who are contaminated externally may contaminate others, either directly or by secondary contamination. Secondary contamination occurs when a contaminated person or object touches something that is then touched by another who then becomes contaminated.

Radioactive material that might not be very dangerous outside the body may be dangerous if allowed to enter the body. For this reason, throughout this training, we will emphasize the use of personal protective equipment (PPE) and the importance of not eating, drinking, smoking, or chewing while on the scene of a radioactive material incident.

The following example describes how contamination is often spread. Imagine chalk on a blackboard is radioactive material. If the chalk dust is transferred to your hands, you are considered contaminated. From your hand, the chalk dust can then be transferred to your shirt. The transfer of contamination from your hands to your shirt is an example of secondary or cross contamination.

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SOURCES OF RADIATION

Everything is exposed to background ionizing radiation from naturally occurring sources. Radiation is found everywhere: in the earth's crust, in water, in the air, and in cosmic rays and particles. A portion of the world's population is also exposed to man-made sources of radiation through medical procedures that use radioactive material and X-rays. Even our bodies contain naturally occurring radioactive material.

What does radioactive material look like? As with other hazardous material, radioactive material exists in all physical forms-solids, liquids and gases. The following are some commonly used and transported radioactive materials:

Radiopharmaceuticals - radioactive drugs used for medical diagnoses and in radiation therapy. These materials can be in liquid, gas, powdered, or solid form.

Consumer products - smoke detectors, antique ceramic plates, radium dial watches, some exit signs, and some types of lantern mantles.

Radiographic sources - specially designed and sealed sources of

high-level radiation used in construction and other industrial applications to check welds and metal for flaws, to check concrete and asphalt, and to test the density of soil.

Nuclear fuels - nuclear fuel may be either new fuel being transported

to a nuclear power station or spent (used) fuel being transported for reprocessing or disposal. These materials are typically in solid form and transported in specially designed packages called shipping casks.

Radioactive waste - material from nuclear power generating facilities, nuclear processing plants, research institutions, medical facilities, or other locations where radioactive waste is generated.

Uranium ores - natural rock material transported from mines and

mills to purification processors then to manufacturing facilities.

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Radioactive material is commonly produced and used at DOE laboratories and commercial facilities, and the material must be transported to and from the facilities under strict guidelines for safety.

Radioactive material is the most highly regulated hazardous material transported. The U.S. government regulates domestic shipments of radioactive material. This responsibility is shared by the Department of Transportation, the U.S. Nuclear Regulatory Commission, and the U.S. Environmental Protection Agency. The philosophy for managing the transport of radioactive material is highly proactive. The emphasis is on preventing incidents from occurring, and this proactive approach works. Radioactive material has been moved across this country for more than 50 years and, to date, there has never been a death or injury resulting from exposure to this material during transport.

Check Your Understanding

1. Atoms are made up of ______, _______, and ________.

2. _________ radiation is more energetic than other types of radiation.

3. Ionizing radiation is radiation that has the ability to cause a _______ change in atoms.

4. Radioactive material is any material that emits _______.

5. The process of an unstable atom emitting radiation is called ____________.

6. Radioactive material in an unwanted location is called ___________.

7. ________ can pass through the body; ___________ can be deposited in or on the surface of the body.

8. One common source of radioactive material is (pick one):
   a) Radio waves
   b) Visible light
   c) Radiopharmaceuticals
   d) Microwaves

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ANSWERS

1. protons
   neutrons
   electrons
2. Ionizing
3. physical
4. radiation
5. radioactivity
6. contamination
7. radiation
   contamination
8. c